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AESTHETICS AND THE ART OF ENGINEERING

Per Boelskifte,
Technical University of Denmark (DTU)

1.0 ABSTRACT

The involvement of engineering with aesthetics is vital for the creation of innovative and successful products in today's fast changing world. This paper discusses the nature of this involvement historically and in the present, and goes further to argue that aesthetics plays a central role in the creative process itself. Thus, if engineers are involved in the creation of products, or if they wish to have more impact through their creativity, it is important that they be sensitive to the aesthetic implications of their work and also to their personal aesthetic capabilities and limitations. This paper also examines and discusses a few of the reasons why the importance of aesthetics may be difficult for the engineering profession to acknowledge; primarily based on a survey into textbooks used in educating mechanical engineers and engineering designers with the aim to identify [what? -CB]. Finally a possible paradigmatic change in the engineer's approach to aesthetics is presented and discussed.

Keywords: Aesthetics, styling, emotion, design, engineering design, industrial design, mechanical engineering.

1.1 INTRODUCTION

When looking at textbooks and curricula in engineering education it is neither easy to find study material nor courses focusing on – or even including aesthetics. If aesthetics is understood as having to do with a high level perception of quality, it becomes evident that most engineering decisions may affect the aesthetics of a solution be it a product, a building, a ship or a system. But aesthetics is often, quite mistakenly, associated with surface beauty rather than having to do with evoked emotions and feelings. Defined in the former way, aesthetics seems to be regarded by engineers as of peripheral concern, and, if required, aesthetic elements can be easily applied by an industrial designer at the very last phases of the development process. Engineering today is by many seen as a scientific pursuit that investigates materials and processes in ways that are only slightly more applied than physics. As a result, aesthetics seems like a rather fuzzy subject, especially in academia where acknowledgments and respect come to those who conduct research within the natural science paradigm (Faste 1995).

During the 1990s, a number of engineering schools started new lines of education emphasizing engineering design skills and introduced new aspects into the curriculum of engineering design.

These additions included industrial design, science, technology and society studies (STS), user ethnographies, and market analysis. Examples of these reformed engineering programs can be found at, e.g., Delft University in the Netherlands, Rensselaer Polytechnic Institute in U.S.A., the Technical University of Denmark, the Norwegian University of Science and Technology, and several other places (Jørgensen et al., 2011).

The majority of engineering curricula in the related areas of engineering design and mechanical engineering have only changed little, even if the need and challenge to expand engineers' understanding of aesthetic has existed since the 70es. To get an impression of the present situation, a survey has been conducted based on engineering textbooks. They have been investigated for content pertaining to aesthetics directly and indirectly.

These textbooks are, in some cases, used worldwide and not only by the aforementioned universities, and should give a good quantifiable indication of the role of aesthetics in the education of engineers. The textbooks are all in English.

1.2 BACKGROUND

The beautiful, the true, and the good - these elements form the triad of fundamental values that have been recognized in a European cultural context since antiquity as the intrinsic qualities from which all values are derived (fig. 1).

The following examples of Ørsted and his context followed by a description of the important societal developments between two world exhibitions are used to illustrate the journey of engineering distancing it from aesthetic paradigms.

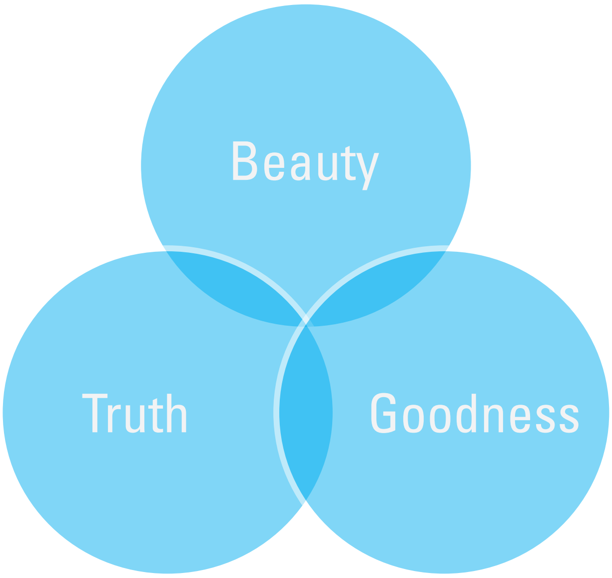

Fig.1 The triad of fundamental values

The Danish physicist and philosopher Hans Christian Ørsted is best known for discovering the relation between electricity and magnetism known as electromagnetism; but Ørsted had a wide range of interests, including education, philosophy, politics, and literary affairs. Ørsted was an enthusiastic supporter of Danish writer Hans Christian Andersen, and he also introduced more than 300 new words to the Danish language including the words Brint and Ilt for hydrogen and oxygen, respectively, and Ildsjæl literally meaning "fiery soul" describing a person with great enthusiasm and work capacity. Ørsted had those qualities himself. In 1824, Ørsted founded the Society for the Dissemination of Natural Science, which he stated was for the purpose of "spreading knowledge about experimental science, the mechanical part as well as the chemical part." At the same time he involved himself in discussions with and gained inspiration from Kant and later Hegel. Ørsted's combination of scientific thinking and wide-ranging intellectual and practical efforts in cultural, philosophical and political activities helped transforming the Danish society in the mid 18-hundreds. Ørsted believed that Denmark would best progress as a country through a close cooperation between science, research and industry. To help ensure that all of the small country's human resources were fully utilized, Ørsted emphasized the need for a comprehensive nationwide system of education and training. From 1829 until the time of his death in 1851, Ørsted was founder and head of den Polytekniske Læreanstalt - the Polytechnic, which today is known as DTU, the Danish University of Technology. In Stockholm, Sweden, KTH - The Royal Institute of Technology was founded two years earlier in 1827. Over the formal entrance you can still see the emblem stating: KTH - VETENSKAP OCH KONST, KTH SCIENCE AND ARTS. The two Scandinavian institutes followed the founding of a number of polytechnical schools in Europe. Most were based on the model of Ecole Polytechnique established 1794 in Paris. Thanks to people like Ørsted, polytechnics in the early half the 19th century became experimental, holistic innovator of both society and technology.

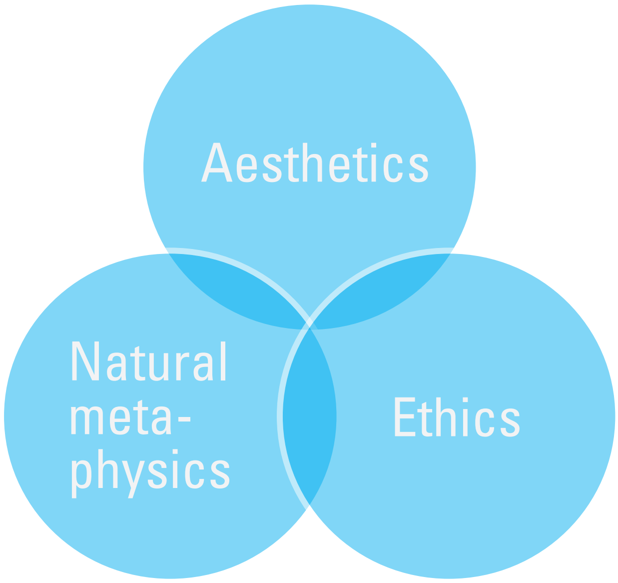

Fig.2 The Ørsted triad in the author's interpretation.

What happened to aesthetics and the art of engineering? Over the latter part of the 19th century the discourse between romanticism and positivism caused a shift in the engineering approach. Until then technical phenomena were addressed as part of metaphysics or the Ørsted term Naturmetafysik Natural Methaphysics (Kant) and later Natural Philosophy (Hegel) (Fig. 2); but it gave way to a scientific method approach transforming natural philosophy into an empirical activity based on controlled experiments setting it apart from the rest. The polytechnic was gradually replaced by what I refer to as the monotechnic i.e. a engineer highly competent in a limited field – a tribologist for example. So the creative, holistic, and experimenting engineer was gradually succeeded by a scientific, “conservative” engineer. The bonds to aesthetics and ethics are mostly severed in this process. The World’s Fair exhibitions of culture and industry became a very popular 19th-century series of events. Two of them are described in this paper to illustrate the rapid development in the separation process of the arts and technologies. The first, called “The Great Exhibition of the Works of Industry of all Nations” took place 1851 in The Crystal Palace designed by Joseph Paxton, which was situated temporarily in Hyde Park, London.

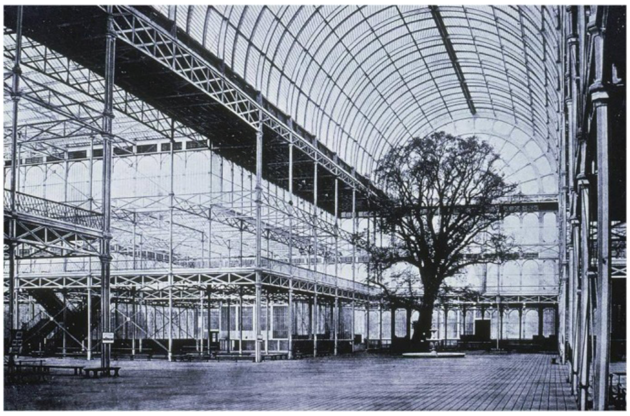

Illustration 3. The Crystal Palace in Hyde Park. 1851

The impressive, beautiful and modular masterpiece built mainly from cast iron and plate-glass components covered an area of 80.000m2 (12 soccer fields!). Inside this transparent wonder were exhibited the very best each nation had to offer in materials, machinery, processes, and works of art. As an indicator of things to come, the considerable surplus of the successful exhibition was later used to fund The Victoria and Albert Museum, The Natural History Museum and The Science Museum. The old trinity was breaking up and assigned separate positions.

The Exposition Universelle in Paris further demonstrated the widening of the gap.

On the huge exposition grounds the Tour Eifel, named after its creator, rose as the main symbol of the event, and like the Crystal Palace, in my opinion a masterpiece and an icon making a strong visual statement: The art of engineering – L’art du

Illustration 4. The World Exposition site in Paris 1889 with the Eifel Tower in the foreground, to the left and right the palaces of fine arts and liberal arts, and in the background the Galerie des Machines.

Ingenieur was not totally a thing of the past although it did not occur to a majority of spectators who could not wait to see the structure demolished!

On the exhibition site the second most impressive and daring structure, with a length of 420m and a free span of 110m, was the Galerie des Machines designed by the architect, Dutert and the engineer, Contamin. Close to The Eifel Tower and perpendicular to the Palace of Machines stood the Palace of Liberal Arts and the Palace of Fine Arts.

This distinct layout signifies how the triad of fundamental values, so important to Ørsted and his contemporaries and manifested in the first World Exposition in London, had been drifting apart due to new developments in each field and in Paris, 38 years later, also had been assigned each their individual palace and position.

How did this separation affect the approach to polytechnic education and its curricula? Can we trace this development to the present time? Is the separation still in effect or is the affinity between engineering and the arts becoming visible.

1.3 THE ROLE OF AESTHETICS IN ENGINEERING TEXTBOOKS

To get a first hand impression and mapping a study of 15 textbooks of engineering design was carried out. They were published from 1976 to 2008. Concluding from the survey only few textbooks addresses aesthetics. A third of the textbooks does not contain any mention of aesthetics. Only a few of the textbooks has more than 3% of their content addressing aesthetics directly or indirectly.

Title of textbook	Author	Year(s)	Pages total	Pg. on aesthet-ics	Pg. on related subjects	Related Illustra-tions used	App. % of book's contents
Systematic Design of Industrial Products	Tjalve (DK)	1976, 1978	233 207	6	53	+	30%
Engineering Design	Dieter (USA)	1983, 2000	798	6	4	+	2%
Integrated Product Development	Andreasen & Hein (DK)	1985, 1987	205	0	?	?	-
Total Design	Pugh (UK)	1990		1	0	-	> 1%
The Mechanical Design Process	Ullman (USA)	1992	337	5	2	+	2%
Product Design	Baxter (UK)	1995	307	17	34	+	17%
Engineering Design	Pahl & Beitz (D)	1995	544	9	0	+	> 2%
Product Design: Fundamentals and methods	Roozenburg & Eekels (NL)	1995	408	2	+	-	> 1%
Product Design and Development	Ulrich & Eppinger (USA)	1995 2008	368	6	19	+	5%
Mechanical Design	Childs (GB)	1998 2004	358	3		+	> 2%
Engineering by Design	Voland (USA)	1998 2004	610	0	0	-	-
Engineering Design Principles	Hurst (USA)	1999	167	4	0	+	> 3%
Introduction to Engineering Design	Samuel & Weir (UK)	1999	405	2	0	-	0.5%
Engineering Design Methods	Cross (UK)	2000 2008	217	4		+	2%
Engineering Design: A Project Based Introduction	Dym & Little (USA)	2003 2008	226 352	?	?		-

Table 1: A survey of 15 engineering design textbooks widely use

Those books found most interesting and representative are described in the following: These textbooks are, in some cases, used worldwide, and not only by the aforementioned universities. They have been selected both to represent textbooks with highly original content and also some more "mainstram" publications. Two classic examples of the former are *A Systematic Design of Industrial Products* (Tjalve, 1976; English ed. 1978) originally published with the title of *A short Course in Industrial Design* on the publisher's insistence (!) and *Engineering Design, A Systematic Approach* (Pahl and Beitz, 1995). A more anthological approach is seen with *Product Design and Development* (Ulrich and Eppinger 1995, 4th ed. 2008)

The textbook *A Systematic Design of Industrial Products* (Tjalve 1976) was written for students at degree- or diploma level in industrial- and engineering design educational programmes, whether with an art – or technical background. It was also intended for professionals working with the creation and development of manufactured products, whether they were intended for the industrial- or consumers markets. As seen in table 1 the textbook contains one of the highest percentages of content with an aesthetic approach. The textbook scores high on Subjects related to Aesthetics: Topics such as: Design, Designer, Appearance of a Product, Form Concepts, and Form Design.

Tjalve's *Product Synthesis* is still widely used and referred to. In my professional work as a industrial designer my partner Christian Bjørn and I worked with Tjalve in 1980 to 1984. In hindsight we found his model wanting in the sense that it did not include formgiving until at the end of the process. But we did not discuss the matter with him.

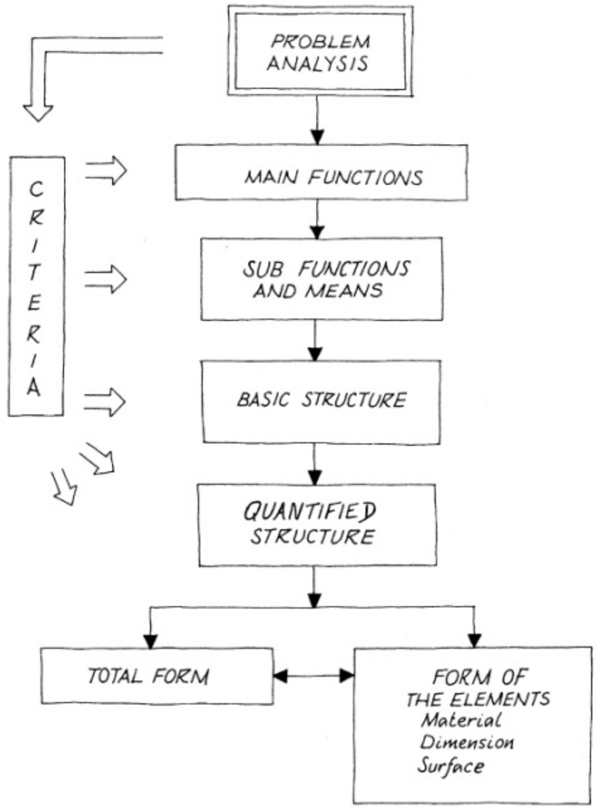

Fig. 2 : The Product Synthesis by Tjalve. The model shows the stages of the design process.

The book is richly illustrated as such – and has a good number of illustrations related to aesthetic incorporating it as a natural element in the development process.

The illustrations in Tjalve's textbook have remained unaltered since 1976 and the generic form studies still work well, while, as an example, the side pictures of car´s illustrating rhythms in design seem anachronistic. This may pose a danger since students tend to not accept textbooks with lack of updates regarding illustrations. It also tells us something regarding aesthetics and it's interpretations to some degree depending on a particular context. Aesthetics is in many aspects a moving target with a dependency on particular situations and cultural backgrounds.

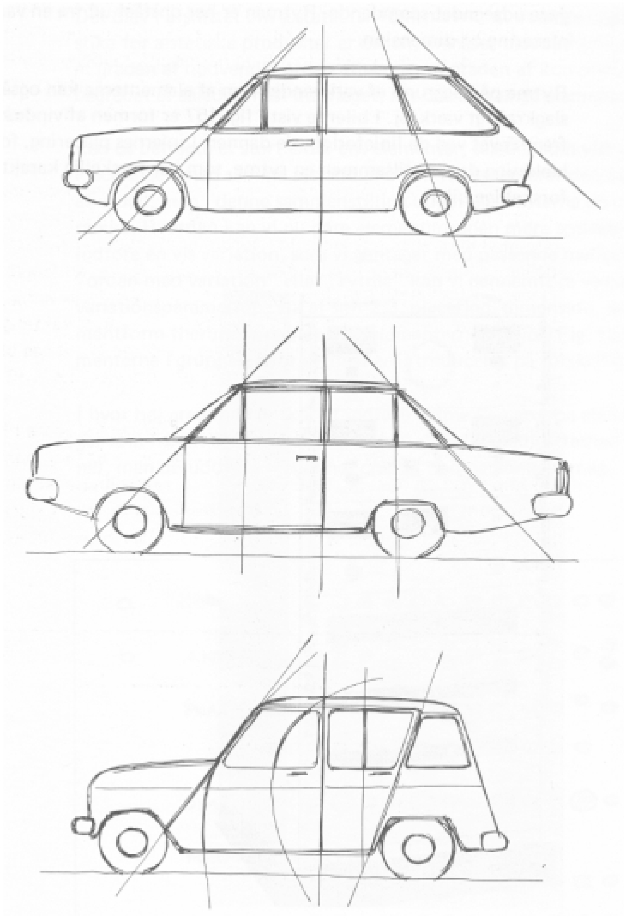

Illustration 1: Tjalve. Three cars where the prominent lines gives different rhythms. The last car example can be identified as a Renault 4L produced in a number of varieties from 1961-1992.

The textbook *Engineering Design: A Systematic Approach* (Pahl and Beitz, 1995) is a cornerstone in engineering design literature. Sidney Gregory from London School of Art did a review with the headline *A Milestone or a Tombstone?* The book has a modest number of pages devoted to form giving and aesthetics. Again the prescriptive examples are illustrated with anachronistic illustrations that may not be so inspiring to the present time reader and seem to be dutifully included.

In the widely used textbook *Product Design and Development*, Ulrich and Eppinger divide the book into thematic entities that can be read independently. The book offers an entire chapter on Industrial Design and an effort is being made to update product examples and the related illustrations in each new edition.

The last two noteworthy textbook examples are Baxter's *Product Design* (Baxter, 1995) , and Larry Buciarelly's *Designing Engineers*. (Buciarelly, 1994)

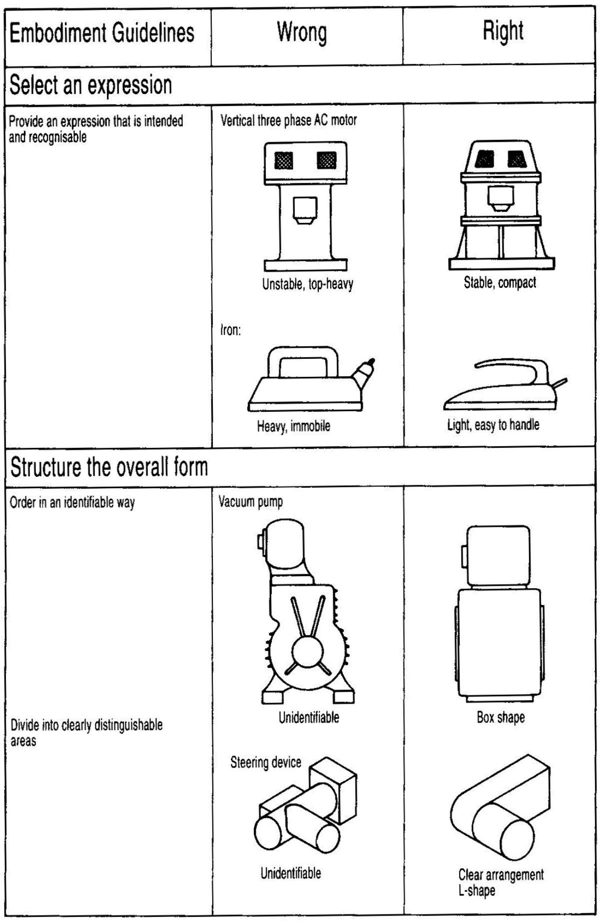

Figure 7.100. Embodiment guidelines for aesthetics: expression and structure.

Illustration 2. Pahl & Beitz. Engineering Design. A Systematic Approach.

On Baxter: The scope of this book is intended to cover all aspects of product development for mass-produced products. It is concerned with industrial and engineering design rather than architectural design or design for craft production. This makes it a very comprehensive textbook well suited for basic courses. But the publication date (1995) also makes this publication slightly anachronistic when it comes to a number of illustrations.

Buciarelly writes in the foreword of his textbook Designing Engineers: “This is a book about engineering design, but it is not a picture book. I will offer no illustrations on automobiles sporting sleek, aerodynamic shapes, or of glistening kitchen appliances, or of sky-view offices with dispersed computer monitors and attractive people lounging about. Such visions rapidly become dated, like fashion in clothes or tubes of tooth paste. I will take my chance with words. They endure somewhat longer.” It is hard to imagine a textbook addressing aesthetic issues not being illustrated at all. Is this indicative of shyness or wish for longevity of the text on the author’s part?

1.4 CURRENT AESTHETIC APPROACHES IN ENGINEERING

A number of new approaches that include aesthetics have been introduced over the past few decades:

A well known and much used approach is Design for X (DfX) It refers to the high number of methods and tools that can be applied in the product development process with a focus on various stages of the intended solutions lifecycle: The Development- , manufacturing -, utilisation -, and disposal phases. It also refers to “Design of Exellence”.

Design for Quality is an X-dimension dealing with a number of quality aspects, and some research have been made with both product quality (q) and user experienced quality (Q) incorporated (Myrup Andreasen and Mørup, 1994). An interesting task would be to attempt developing a Design for Aesthetics method.

Kansei Engineering can be described as Affective Engineering (Yamamoto, Nagamachi 1986) Kansei Engineering parametrically links customer’s emotional responses whether physical or psychological to product and/or services with their properties and characteristics. In consequence, products can be designed to bring forward the intended feeling. Kansei/Affective engineering is a distinct approach to extract user information. “Kansei is the impression somebody gets from a certain artefact, environment or situation using all the senses of sight, hearing, feeling, smell, taste as well as their recognition.”

Kansei engineering can be either used by designers as a design aid to develop products that are able to match consumers’ Kansei or used by consumers to select products based on their Kansei requirements To obtain Kansei data for the products to be evaluated, the most commonly used method is to identify and measure Kansei attributes (attributes having a bipolar pair of Kansei words) first and then ask people to assess their feelings regarding these Kansei attributes, in which the semantic differential method is often used. (Hong-Bin Jan et al.) This approach attempts to numerically model aesthetics which might endear it to skeptics favoring quantifiability.

The dissertation Products as Representations. A Semiotic and Aesthetic Study of Design Products (Vihma,1995) launched a branch of semiotics for the Design domain arguing that Design Semiotics should be an instrument for investigating the semantic dimension of design.

Later investigations was made in Semantics and Materials Choice, and Verbal Communication of Semantic Content in Products (Boelskifte, Lenau 2004, 2005) The purpose of the research was to explore how precise verbal communication can capture the semantic content of physical products. The results of the research indicated that there exists a mutual understanding of many of the terms describing the qualities and properties in products and that successful verbal communications of sensory and perceived product qualities are possible. A number of the selected terms appeared, though, to have several interpretations causing ambiguous information exchange. The work also suggested that more emphasis was needed in engineering design education for training more precise verbal communication concerning references to semantic contents and relations in products as sign vehicles

Illustration 3. Product examples from Communication of Semantic Content in Products

Since it's upstart more than 35 years ago TU-Delft faculty of Industrial Design Engineering has introduced the approaches of other research fields into their engineering design curriculum. Six comprehensive research programmes have been defined for Industrial Design Engineering. One of these programmes , User Experience, help provide foundational multidisciplinary knowledge for the discipline of industrial design especially at the human-product interaction level, and the product level, respectively evolving around 4 themes: Theme 1: Sensory and cognitive fluency. Enhancing daily human-product interaction. Theme 2: Faces of Understanding the process of user experience: Aesthetics, meaning and emotion. Theme 3: Context around use: Culture, situation and sociability. Adapting the design process to user-context of interaction. Theme 4: Usage, comfort and safety. Optimizing product usage, comfort and safety. (www.io.tudelft.nl)

In Theme 2 research has been conducted to measure the emotional impact, and as a result the Product Emotion Measurement instrument (PrEmo) has been developed (Desmet, 2002). PrEmo is a computer program, developed as an instrument for evaluation of emotions, elicited by products.

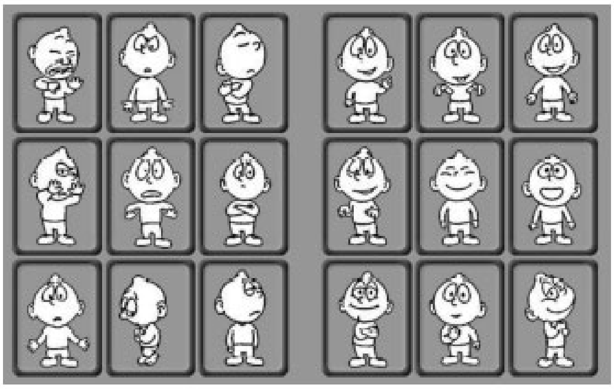

Illustration 4. The emotional characters of PrEmo

PrEmo was developed to aid the understanding of the relationships between the product's appearance and its emotional impact on users. This understanding is intended to help designers improving the emotional impact of their solutions.

It has been shown that a number of new approaches in engineering design education is beginning to have an impact, but mostly still not manifested in the literature investigated. Usage of new media may – as in PrEmo – be part of the future curriculum and in some cases start replacing some of the traditional textbooks, and maybe also be the indication of the emergence of researchers and educators with different and innovative approaches:

"Good engineering design implies (delightfully) harmonious interaction, at the human-technical interface, whereby the product dissolves into an extension of the user. Teaching good engineering design aesthetics to engineering students requires engineering faculty who are enthusiastic about the arts in general and who are sensitive to the aesthetic aspect of their own work." (Charles C. Adams, 1995)

1.5 DISCUSSION

How can aesthetics be introduced, or in some cases better introduced into engineering design curricula, and consequently have a positive effects on the aesthetic competences and approaches of new generations of engineers?

Why is it important to build or strengthen the engineer's competences in aesthetics?

The development of new solutions mostly takes place in multi-disciplinary teams. So whether this process is focused on architecture, product-, ship- or airplane design it is important that the interaction does not lead to compromises one way or the other including aesthetics.

What is aesthetics in this context?

In the widest sense it is the perception of solutions (artefacts) in a cultural context. As indicated previously this is a moving target, so the actors have to look forward with a good understanding of the past.

How should engineers perceive this?

As something of inherent value to a particular solution (artefact) whether it has happened intentionally or unintentionally in the development process. Engineers must know aesthetics are embedded in artifacts, and that aesthetics are governed by subjective criteria. They must also understand that a discourse with partners, that are often better qualified, is a necessity in the definition- and developing process, and that it cannot be expected of engineers to determine aesthetic properties singlehandedly.

What are the main obstacles for a re-unification of engineering and aesthetics?

The educational background of engineers sometimes makes them ill-qualified to work with and amongst actors of equal, but different backgrounds caused by lack of insight.

Engineers today are rather helpless when it comes to criteria which are difficult to quantify and calculate. There are also issues they do not understand, and designers do not understand that engineers do not understand these issues! This often causes frustrations and tensions.

How were these obstacles created?

The technical disciplines in mechanical engineering have only sparsely developed traditions for research into the process and the organisational patterns which create new products, processes and services. It is not regarded as scientific and therefore, it is only partially recognised that the area of product development, and thus aesthetics, is teachable supported by research. The dominant views of design competence seem to be trapped in between three positions neither of which provides a satisfactory answer to the first challenge mentioned. The first position is the mentioned attempt to build a rational, scientific model of the design process which may have some relevance for solving closed problems or optimizing within a finite universe of alternative configurations, but neither reflects the open ended and constructive aspects of designing nor the complexity of interpretations among actor of the problem and solution spaces and how they can be linked together. The second position reflect the open ended, creative and even artistic aspects of designing resulting in an individualistic and singular solutions space where the linking between design, use, function and emotions are left to creativity that reflects both experience and training, but also an ability to combine and make sense of things that favor impressions for analysis. The third position is the skillfulness and trained capacity of the continued repetition related to the personal building of a repertoire of references and inspirations that typically is the core in all training of designers. (Jørgensen et al. 2012) Some of this is also addressed in a dissertation"Kunst und Wissenshaft in der Technic des 20. Jarhundert" (Heymann, 2005) the main thesis of this being that the development of the integration was arrested by a highly digressive discussion on engineering design as an art or a science.

How are aesthetics to be (re)introduced more strongly into engineering design curricula?

Aesthetics could be a part of a more general "Design Thinking" course mandatory to all students in engineering education dealing with the appropriateness of artefacts and how to achieve it or it could be a deep-dive provided only at specific study lines with long term courses immersing the students in problems that provide them with actual design expertise and providing understanding and skills in aesthetic aspects.

The former has the risk of becoming a "Design for Dummies" course but the latter has been successfully introduced at a number of universities as mentioned in the introduction in this paper and present more solid bases for a paradigmatic change concerning an aesthetic approach.

1.6 CONCLUSION

Engineering design is an expanding field worldwide. Since the majority of engineering curricula and syllabuses in the related areas of engineering design and mechanical engineering have only changed little, more emphasis should be given to the study of the practice domains in which the graduates may work in the future.

With the focus of this paper the main question is: How can aesthetics be introduced, or in some cases better introduced into engineering design curricula, and consequently have a positive effects on the aesthetic competences and approaches of new generations of engineers?

Aesthetics should be introduced at different levels depending on the student's qualifications and ambitions: For engineering student in general it could be through interdisciplinary project work including students from other disciplines i.e. architecture, design and business. Through this work the aesthetic dimension, as well as other important issues, are introduced through a holistic approach to need assessment, problem identification and problem solving. The challenge lies in the teachers coming together providing a comprehensive challenge. Finally students with special talents or interest should be encouraged to study for a period at educational institutions with a higher focus on aesthetics.

For students with an engineering design background aesthetic issues should be introduced in dedicated "primer courses" where aesthetics play an important role in the syllabus with industrial design as the main theme. Following that, advanced courses should then be offered where master student could be challenged with complex design assignments using their foundation from the basic courses.

Finally the engineering design students should be encouraged to approach and deal with aesthetic dimension in both their bachelor and master thesis's. This calls for a well structured curriculum with a fine tuned syllabus and textbooks to match.

The holistic, synthesis oriented engineer is slowly returning. At a number of universities it is manifested by a number of new schools and curricula, all with a very high number of students applying so a good process has started up, but it will still take a long time for significant changes to happen. Excellent long-term results have been seen at TUDelft and NTNU to name a couple, turning out graduates with a more holistic view of engineering and the arts and the graduates have positioned themselves in a big number of businesses and organizations influencing the change, but many more universities are needed to take this challenge on and help to speed up this paradigmatic change. But universities must identify and utilize the "fire-souls" to head the projects and a supportive management most efforts are doomed to fail.

REFERENCES

Baxter, Mike R. (1995). *Product Design: A Practical Guide to Systematic Methods of New Product Development*. London: Chapman & Hall.

Bucciarelli, Louis L. (1994). *Designing Engineers.* Cambridge, Mass.: MIT Press.

Childs, Peter R. N. (2005). *Mechanical Design.* Amsterdam: Elsevier/Butterworth-Heinemann.

Cross, Nigel. (2006). *Designerly Ways of Knowing*. London: Springer-Verlag London.

Cross, Nigel. (2008). *Engineering Design Methods: Strategies for Product Design* (4. ed). Chichester: Wiley.

Desmet, Pieter. (2002). *Designing Emotion*. Delft University of Technology, Delft.

Dieter, George Ellwood. (2000). *Engineering Design: A Materials and Processing Approach* (3rd ed). Boston, Mass. [u.a.]: McGraw-Hill.

Dym, Clive L., Little, Patrick, & Orwin, Elizabeth J. (2009). *Engineering Design: A Project Based Introduction* (3rd ed.). Hoboken, NJ: Wiley.

Faste, Rolf. (1995). The Role of Aesthetics in Engineering. *Japan Society of Mechanical Engineers (JSME) Journal,* Winter 1995.

Hein, Lars, & Myrup Andreasen, Mogens. (1985). *Integreret produktudvikling*. København: Jernets Arbejdsgiverforening.

Heymann, Matthias. (2005). *"Kunst" und Wissenschaft in der Technik des 20. Jahrhunderts: Zur Geschichte der Konstruktionswissenschaft.* Zürich: Chronos.

Hurst, Kenneth S. (1999). *Engineering Design Principles.* London: Arnold.

Jørgensen, Ulrik, Brodersen, Søsser, Lindegaard, Hanne, & Boelskifte, Per. (2011). Foundations for a New Type of Design-Engineers: Experiences from DTU. Paper presented at the *International Conference of Engineering Design, 2011.*

Mørup, Mikkel. (1994). Design for Quality. (Ph.D. Dissertation), Technical University of Denmark

Myrup Andreasen, Mogens, & Hein, Lars. (1987). *Integrated Product Development*. Bedford, UK: IFS.

Pahl, Gerhard, Beitz, Wolfgang, & Wallace, Ken. (1996). *Engineering Design: A Systematic Approach.* London: Springer London.

Pugh, Stuart. (1990). *Total Design: Integrated Methods for Successful Product Engineering*. Wokingham: Addison-Wesley.

Roozenburg, Norbert F. M., & Eekels, Johannes. (1995). *Product Design: Fundamentals and Methods.* Chichester: Wiley.

Tjalve, Eskild. (1976). *Systematisk udformning af industriprodukter*. København: Akademisk forlag.

Ullman, David G. (1992). *The Mechanical Design Process*. New York [u.a.]: McGraw-Hill.

Ulrich, Karl T., & Eppinger, Steven D. (2006). *Product Design and Development* (3rd ed.). Boston, Mass.: McGraw-Hill.

Vihma, Susann. (1995). Products as Representations: A semiotic and aesthetic study of design products. (Ph.D. Dissertation), University of Art and Design Helsinki, Helsinki.

Voland, Gerard. (2004). *Engineering by Design* (2nd ed.). Upper Saddle River, N.J.: Pearson/Prentice Hall.

Yan, Hong-Bin, Huynh, Van-Nam, Murai, Tetsuya, & Nakamori, Yoshiteru. (2008). Kansei evaluation based on prioritized multiattribute fuzzy target-oriented decision analysis. *Information Sciences, 178*(21), 4080-4093.

CORRESPONDENCE

Per Boelskifte, Department of Mechanical Engineering, Technical University of Denmark, Produktionstorvet, Building 426, room 152, 2800 Kgs. Lyngby.
Email: pboe@mek.dtu.dk

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